High Tunnel Greenhouse

Team Stand Your Ground

Senior Lab Project Proposal

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Introduction

Background:

A grower in the area of Buhl, Idaho has constructed several greenhouses but is looking for a new design which will be more resilient in the high winds and heavy snows of the area. In the past, greenhouses have failed due to both high wind speeds and heavy snow loads. Due to the available plot of land the greenhouse must be oriented with its flat end facing into the wind. As a result of this orientation the ends of the greenhouse have blown in during high wind gusts. The sustained wind speeds range between 25 to 30 mph, and the wind can gust up to 75 mph. Building regulations necessitate designing to a 105 mph wind gust standard at these conditions. The client would like to extend the life of the greenhouse frame to at least ten years and the plastic covering for five to ten years in order to improve the economy of the design. The heavy snow loads will most likely require the use of a Gothic high tunnel frame design. This is because the Gothic frame sheds snow more effectively than the Quonset design. The Gothic frame is shown in Figure 1 and the Quonset frame is shown in Figure 2 below. The design must also take into account accommodating large entrances in the ends.

Figure 1: Demonstrating the Gothic Frame Style

Figure 2: Demonstrating the Quonset Frame Style

Motivation:

The completion of this experiment will influence our design decisions to mitigate the impact of wind on the high tunnel greenhouse. This will benefit our project by substantiating our decisions to alter traditional high tunnel greenhouse designs in order to withstand high wind speeds. Typical greenhouse designs seldom incorporate features directly related to minimizing wind forces. Our experiment will enable the testing of new greenhouse configurations which could help the greenhouse to withstand the necessary wind speeds. We will be able to test the two prevalent high tunnel designs, the Quonset and Gothic frames, as well as alternate designs in order to determine which will best meet our requirements (Blom, Brown, and Hughes 11). This will benefit the client developing a greenhouse that can withstand high wind speeds, thus minimizing repair costs.

The effect of wind on greenhouses is often approximated to calculate a resultant wind force. Studies have also been performed to analyze the effects of wind on multiple greenhouses, typically how they interact when situated side by side to each other (Moriyama, 585-592). However, no experiment has directly tested both the prevalent existing greenhouse designs as well as our design ideas in a wind tunnel. This experiment will yield previously unavailable data which will allow our design to be optimized for our project.

Objective:

The objective of this experiment is to determine a frame design which minimizes the forces on the greenhouse due to wind. This experiment will consider current greenhouse designs as well as several new designs and will determine if any design is significantly better than the others.

Our dependent variable is the drag force on the model. Our factors will include wind speed and frame end design. Wind speed will have one level, the speed (scaled mph). The range for this level will be a high speed of 105 (scaled mph) and a low speed of 30 (scaled mph). The second factor is the frame end design. This will have two levels; Gothic and Quonset. The Gothic level will have a range of Gothic with wind break and flat Gothic. The Quonset level will have a range of Quonset with wind break and flat Quonset. The factors, levels, and ranges are summarized in Table 1.

Table 1: Factors, Levels, and their Ranges

Factors	Levels	Range
Wind Speed	Speed (scaled mph)	30 mph
		105 mph
End Type	Gothic	Flat
		With Breaker
	Quonset	Flat
		With Breaker

Hypothesis:

H_0: Factors do not yield a significant difference in drag force.

H_{01}: there is no interaction effect between design and wind speed.

Alternate:

H_A: at least on factor is significantly different in drag force.

H_{A1}: there is an interaction effect between design type and wind speed.

Methodology

Apparatus:

The experiment apparatus is the University of Idaho's wind tunnel located in the Gauss-Johnson laboratory. This apparatus is summarized in Figure 3. The main principle is to measure the drag force resulting from the air flow through the wind tunnel. The wind tunnel displays drag force, lift force, air speed, and a flow visualization. Our models will be located inside of the clear box shown in Figure 4. The wind tunnel generates air flow which produces a drag force on the model that is then measured using instrumentation located inside of the plastic box. Styrofoam will be used to model the end types for the experiment. The model will be mounted to the force measuring apparatus located within the wind tunnel.

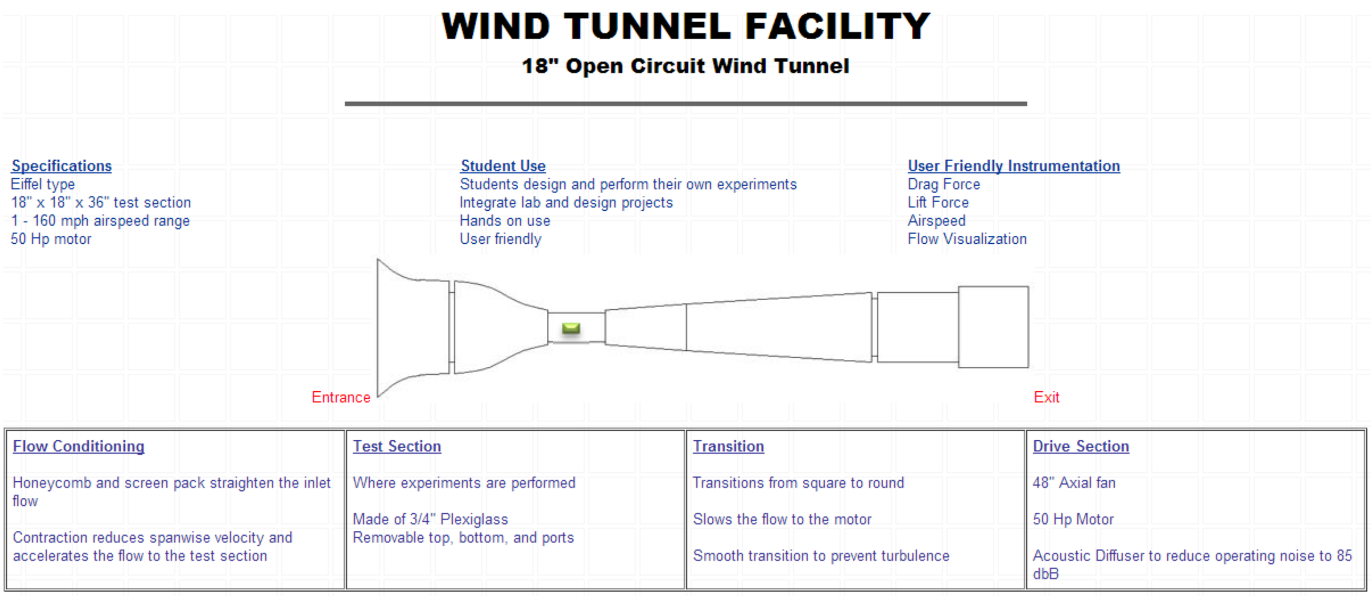

Figure 3: Sketch and details of University of Idaho wind tunnel

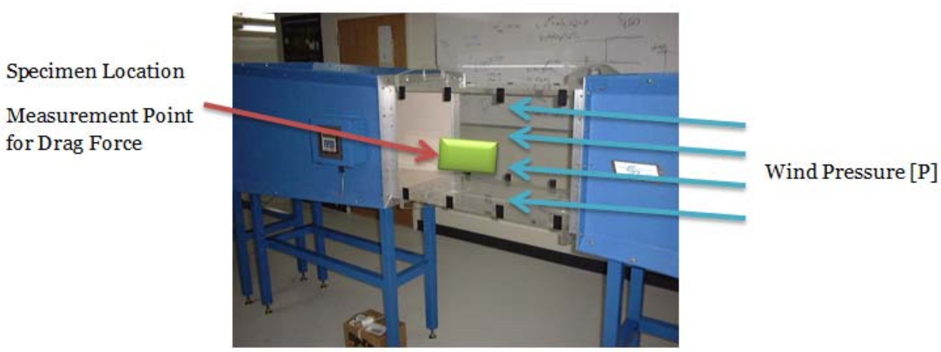

Figure 4: Specimen Location and Measurement Points

Statistical Methodology:

This design procedure requires looking into minimizing the amount of force located on the greenhouse. Our experimental factors, levels and ranges are specified in Table 1. The wind tunnel wind speed will be varied between the high and low range against each of the end types and their ranges, resulting in 32 total measurements with four runs for each configuration. A factorial analysis will be used as a result of having two independent variables. The wind speeds will produce resultant drag forces on the models that will be used as the dependent variable for the factorial analysis.

The drag force accuracy is of minor concern as this test is to see which design produces the least amount of drag force. Some sources for error can come from how the device is mounted. If the model is loosely mounted it may vibrate resulting in more drag. Another source could be how smooth the Styrofoam models are. If each is of different roughness it could result in more or less drag force. The measurement instrument itself could be a source of error if it isn't properly calibrated; it could result in different scales of reading for the high and low settings of wind speed. In addition our accuracy will be limited by the number of digits that the instrument can display.

Costs

The only cost for this experiment will be the Styrofoam used to model the greenhouse end types. This should be a relatively small expense both due to the small amount of material needed and the low cost of Styrofoam. Every additional resource for this experiment is provided without cost.

Reporting

The final report and presentation will be collaborated and drawn up by the group. The final submission of these will be delivered to the BbLearn drop box by an individual of the group. The report will be turned in before the 16th of December and the presentation by the 10th of December. The report will be specifically addressed to Dr. Bauer and Tony McCammon of the Idaho extension program and in general to the scientific community.

References:

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"Gable High Tunnels." *Gothic Arch Greenhouses*. N.p.. Web. 24 Oct 2013. <http://www.gothicarchgreenhouses.com/greenhouse-gable-high-tunnel.htm>.

Moriyama, H, S Sase, Y Uematsu, and T Yamaguchi. "Wind Tunnel Study of the Interaction of Two or Three Side-by-Side Pipe-Framed Greenhouses on Wind Pressure Coefficients." *Transactions of the Asabe*. 53.2 (2010): 585-592. Print.

"Wind Tunnel Facility." *University of Idaho*. N.p.. Web. 24 Oct 2013. <http://www.webpages.uidaho.edu/fluidslab/fluids/windtunnel/wind_tunnel_facility.htm>.